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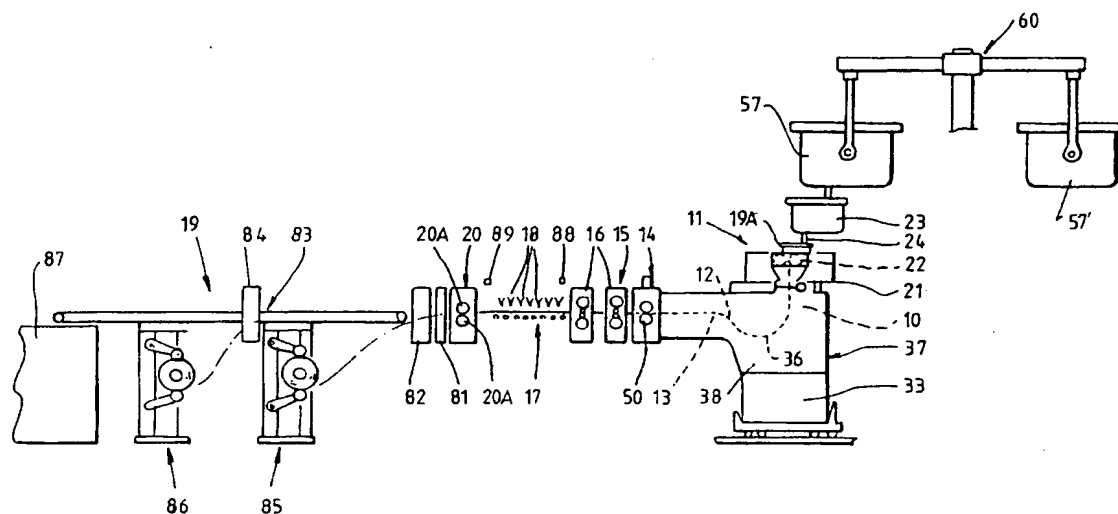
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(54) Title: CASTING STRIP



## (57) Abstract

Twin roll caster (11) produces cast steel strip (12) that passes in a transit path (10) through pinch roll stand (14) and optional hot rolling mill (15) and runout table (17) to a coiling station (19) which has a pair of switchable coilers (85, 86). A strip shear (81) located in advance of the coiling station is operable to sever strip (12) into discrete lengths which can be diverted by setting deflectors (82, 84) to allow the severed lengths to pass across a runout table (83) to a scrap bin (87). The strip may be thus severed and diverted to scrap on development of strip defects or malfunctioning of equipment without stopping continuous casting and the strip redirected to the coiling station when the problem is rectified.

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CASTING STRIP

## TECHNICAL FIELD

5 This invention relates to the casting of metal strip. It has particular but not exclusive application to the casting of ferrous metal strip.

It is known to cast metal strip by continuous casting of strip in a twin roll caster.

10 Molten metal is introduced between a pair of contra-rotated horizontal casting rolls which are cooled so that metal shells solidify on the moving roll surfaces and are brought together at the nip between them to produce a solidified strip product delivered downwardly from the nip between the rolls. The term "nip" is used  
15 herein to refer to the general region at which the rolls are closest together. The molten metal may be poured from a ladle into a smaller vessel or a series of smaller vessels from which it flows through a metal delivery nozzle located above the nip so as to direct it into the  
20 nip between the rolls, so forming a casting pool of molten metal supported on the casting surfaces of the rolls immediately above the nip and extending along the length of the nip. This casting pool is usually confined between side plates or dams held in sliding engagement with end  
25 surfaces of the rolls so as to dam the two ends of the casting pool against outflow, although alternative means such as electromagnetic barriers have also been proposed.

Although twin roll casting has been applied with some success to non-ferrous metals which solidify rapidly  
30 on cooling, there have been problems in applying the technique to the casting of ferrous metals which have high solidification temperatures and a tendency to produce defects caused by uneven solidification at the chilled casting surfaces of the rolls.

35 Strip defects such as, for example, severe transverse cracks may cause the strip to tear and shear and may, during continuous casting, cause a complete

shutdown of operations if adequate provision is not made for effective handling of defective strip on line.

Malfunctioning of the casting or strip handling equipment can also require a complete shutdown of the casting line.

5 Shut downs of continuous strip casting operations are expensive in terms of loss of productivity, in terms of the potential for damage of equipment and in terms of the increase in risk to the health and safety of personnel and other hazards that occur as a result of strip  
10 breakout.

The present invention enables shut downs to be minimised, even when defective strip develops or there is an equipment failure, by allowing diversion of the defective strip to scrap and subsequent take up of strip  
15 for end use when the cause of the defects or equipment malfunction has been rectified, without shutting down the continuous strip casting operation.

#### DISCLOSURE OF THE INVENTION

20 According to the invention there is provided a method of continuously casting and handling metal strip, comprising:

supporting a casting pool of molten metal on one or more chilled casting surfaces;

25 moving the chilled casting surface or surfaces to produce a solidified strip moving away from the casting pool;

guiding the solidified strip along a transit path which takes it away from the casting pool to a coiling  
30 station;

coiling the strip onto a coiler at the coiling station;

operating a strip shearing means so as to sever the strip in advance of the coiling station into discrete  
35 lengths;

diverting the severed lengths of strip from the coiling station to a scrap station; and

halting the operation of the strip shearing means so as to reinstate delivery of continuous strip to the coiling station and directing the reinstated continuous strip to a second coiler at the coiling station.

5 Preferably, a scrap bin is located at the scrap station to receive the severed lengths of strip.

The operation of the strip shearing means and diversion of the severed lengths of strip to the scrap station may be activated in response to observation or  
10 detection of defects in the strip or malfunctioning of equipment employed in the casting or handling of the strip. In this context the term "defects" may extend to any properties or attributes of the strip which may be undesirable for an end user or for further processing.  
15 Such defects may be observed or detected by visual observation by an operator and/or by detection instrumentation.

Specifically, the method may include the steps of inspecting the strip for defects as it passes in said  
20 transit path by means of strip defect detection means located along that path and initiating operation of the strip shearing means in response to an indication from the defect detection means of defects in the strip.

The defect detection means may be operated to  
25 detect variations in thickness of the strip and/or surface defects in the strip.

The defect detection means may comprise an X-ray gauge and a surface defect detector.

The casting pool of molten metal may be  
30 maintained by flow of molten metal from a tundish supplied alternatively by each of a plurality of ladles brought to a pouring position by a rotating turret.

The invention further provides apparatus for continuously casting and handling metal strip comprising:

35 a pair of generally horizontal casting rolls forming a nip between them;

metal delivery means to deliver molten metal into

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the nip between the casting rolls to form a casting pool of molten metal supported on the rolls;

means to chill the casting rolls;

means to rotate the casting rolls in mutually opposite directions whereby to produce a cast strip delivered downwardly from the nip;

strip guide means to guide the strip delivered downwardly from the nip through a transit path which takes it away from the nip;

a pair of coilers at a coiling station selectively to receive the strip from said transit path;

strip shearing means operable to sever the strip in advance of the coiling station into discrete lengths; and

strip diverter means to divert the severed strip lengths from the coiling station to a scrap station.

The apparatus may further include strip defect detection means disposed along said transit path in advance of the coiling station and operable to detect defects in the strip and the shearing means may be operable in response to an indication from the defect detection means of defects in the strip.

There may be a pair of strip deflectors at the coiling station operable alternatively to divert the strip to one or other of the coilers and the strip diverter means may comprise a runout table to guide the severed strip lengths to the scrap station when the deflectors are set in this mode.

#### BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more fully explained one particular embodiment will be described in detail with reference to the accompanying drawings in which:

Figure 1 illustrates strip casting and rolling installation constructed and operated in accordance with the present invention;

Figure 2 illustrates further detail of the strip caster;

Figure 3 illustrates that part of the installation which receives and transports the strip  
5 issuing from the caster; and

Figure 4 illustrates part of a modified strip casting and rolling installation constructed and operated in accordance with the invention.

## 10 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The casting and rolling installation illustrated in Figures 1 to 3 comprises a twin roll caster denoted generally as 11 which produces a cast steel strip 12 that passes in a transit path 10 across a guide table 13 to a  
15 pinch roll stand 14. Immediately after exiting the pinch roll stand 14, the strip passes into an optional hot rolling mill 15 comprising roll stands 16 in which it may be hot rolled to reduce its thickness. The strip, whether rolled or not, then passes onto a runout table 17 on which  
20 it may be force cooled at a cooling station by water jets 18, then through a pinch roll stand 20 comprising a pair of pinch rolls 20A and thence to a coiling station 19 which includes a pair of switchable coilers 85, 86.

Twin roll caster 11 comprises a main machine  
25 frame 21 which supports a pair of parallel casting rolls 22 having casting surfaces 22A. Molten metal is supplied during a casting operation from a ladle 57 to a tundish 23 through a refractory shroud 24 to a distributor 19A and thence through a metal delivery nozzle 19B into the nip 27  
30 between the casting rolls 22. Molten metal thus delivered to the nip 27 forms a pool 30 above the nip and this pool is confined at the ends of the rolls by a pair of side closure dams or plates 28 which are applied to stepped ends of the rolls by a pair of thrusters (not shown)  
35 comprising hydraulic cylinder units connected to side plate holders. The upper surface of pool 30 (generally referred to as the meniscus level) may rise above the

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lower end of the delivery nozzle so that the lower end of the delivery nozzle is immersed within this pool.

5 Casting rolls 22 are water cooled so that shells solidify on the moving roller surfaces and are brought together at the nip 27 between them to produce the solidified strip 12 which is delivered downwardly from the nip between the rolls.

10 Ladle 57 is supported on a rotating turret 60 by which ladle 57 is brought into position above the tundish 23 to deliver molten metal thereto. Once the molten metal in ladle 57 has been downloaded, the rotating turret moves the near empty ladle 57 to a standby station remote from the downloading station and at the same time brings a laden substitute ladle 57' from a standby location into  
15 position above the tundish 23 for downloading thereby providing a substantially continuous supply of molten metal to the tundish. The near empty ladle 57 is refilled at a remote location and returned to the standby location.

20 At the start of a casting operation a short length of imperfect strip is produced as the casting conditions stabilise. After continuous casting is established, the casting rolls are moved apart slightly and then brought together again to cause this leading end of the strip to break away in the manner described in  
25 Australian Patent 646981 and United States Patent 5,287,912 so as to form a clean head end of the following cast strip. The imperfect material drops into a scrap box 33 located beneath caster 11 and at this time a swinging apron 34 which normally hangs downwardly from a pivot 35  
30 to one side of the caster outlet is swung across the caster outlet to guide the clean end of the cast strip onto the guide table 13 which feeds it to the pinch roll stand 14. Apron 34 is then retracted back to its hanging position to allow the strip 12 to hang in a loop beneath  
35 the caster before it passes to the guide table 13 where it engages a succession of guide rolls 41. The guide table comprises a series of strip support rolls 41 to support



the strip before it passes to the pinch roll stand 14 and a series of table segments 42, 43 disposed between the support rolls. The rolls 41 are disposed in an array which extends back from the pinch roll stand 14 toward the  
5 caster so as to receive and guide the strip from the loop 36.

The twin roll caster may be of the kind as thus far described or may be of the kind which is illustrated and described in some detail in granted Australian Patents  
10 631728 and 637548 and United States Patents 5,184,668, 5,277,243 or 5,488,988 and reference may be made to those patents for appropriate constructional details.

In order to control the formation of scale on the hot strip, an installation is manufactured and assembled  
15 to form a single very large scale enclosure denoted generally as 37 defining a sealed space 38 within which the steel strip 12 is confined throughout a transit path from the nip between the casting rolls to the entry nip 39 of the pinch roll stand 14.

20 Enclosure 37 is formed by a number of separate wall sections which fit together at various seal connections to form a continuous enclosure wall.

The function and construction of enclosure 37 is fully described in Australian Patent 704312.

25 Pinch roll stand 14 comprises a pair of pinch rolls 50 which resist the tension applied by the reduction roll stands 16. Accordingly, the strip is able to hang in the loop 36 as it passes from the casting rolls 22 to the guide table 13 and into the pinch roll stand 14. The  
30 pinch rolls 50 thus provide a tension barrier between the freely hanging loop and the tensioned downstream part of the processing line. They are also intended to stabilise the position of the strip on the feed table and feed it in to the rolling mill 16.

35 Accordingly, the strip exits the enclosure 38 by passing between the pair of pinch rolls 50 and it passes into the hot rolling mill 15.

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After leaving the rolling mill 15, the strip passes to run table 17 and through pinch roll stand 20 to the coiling station 19 at which it can be wound alternatively onto two coilers 85 and 86 which are  
5 selectively switched for winding up the strip. Additional switchable coilers may be provided.

To enable operation in accordance with the present invention, there is provided downstream from pinch roll 20 a shear 81, a deflectors 82, 84 a runout table 83  
10 and a scrap bin 87. A strip defect detector in the form of a conventional X-ray gauge 88 is located above the runout table 17 in advance the cooling water sprays 18 and a strip surface defect detection device 89 is located  
15 above table 17 downstream from the sprays 18. X-ray gauge 88 may be operated to monitor thickness variations in the strip. The surface defect detection device may be an optical scanner or an array of sensors to receive visual or other forms of radiation from the strip surface.

In normal production, deflectors 82, 84 are  
20 selectively operable to deflect the strip to the selected coiler 85 or 86 and to enable the strip to be redirected to change coilers when one coiler has been filled, so allowing effectively continuous casting and coiling.

If either of the strip defect detectors detects  
25 a deterioration of strip quality to the extent that it is suitable only for scrap, then shear 81 may be operated to cut the defective strip into discrete lengths and deflectors 82, 84 are operated so that the cut lengths of strip pass along a runout table 83 to a scrap bin 87 at  
30 the end of the line.

The scrapping of defective strip is continued until the quality of the strip improves or the casting process is stopped. Downstream scrapping of strip in this manner facilitates smooth continuous operation of the  
35 caster. It eliminates the need to stop casting by either dumping the molten metal or casting strip into the scrap box below the casting rolls. Although this box is capable

of handling a quantity of molten steel and scrap strip, it is limited in size.

Downstream scrapping of strip also eliminates the coiling of material, which is not suitable for the intended use. Coiling all material into discrete coils, regardless of the quality, would require additional processing to separate the unsuitable product from the suitable product and may result in more product lost due to restrictions on minimum acceptable coil weights.

Downstream scrapping of the strip may also be used to maintain continuous casting operations in the event of the coiling station becoming completely or partly unavailable. This may be due to a complete or partial equipment failure of the deflectors, the coiling station or downstream equipment. In this case the casting operation could continue while the equipment fault is rectified.

If the cause of the strip defects can be overcome to rectify the strip quality or the coiling station becomes available as casting continues, the shear 81 is deactivated and the appropriate deflector 82 or 84 is operated to redirect the strip to the standby coiler 85 or 86. The method of the invention thus permits scrapping of defective strip in the middle of a production run and redirection of the strip onto a new coiler when the defects have been rectified, without interrupting continuous casting. Continuous casting may therefore proceed over long production shifts with delivery of molten metal being maintained through the rotating ladle turret system.

Figure 4 illustrates a modification by which the enclosure 37 is extended to enclose the rolling mill 15 so that the strip is rolled before it leaves the enclosure space 38. In this case, the strip exits the enclosure through the last of the mill stands 16 the rolls of which serve also to seal the enclosure so that the separate sealing pinch rolls are not required.

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It is worth noting that while there are similarities between a conventional hot strip mill operation and a strip caster, there are major differences between the two.

5 A conventional hot strip mill is a semi continuous or piece process with individual slabs being rolled to create individual or multiple coils. The hot strip mill process can easily be stopped to rectify a defect cause and restarted once the cause has been  
10 eliminated, with some individual loss of product. A strip caster is a completely continuous process, which cannot be easily stopped and restarted, and therefore requires a means to remove a defective portion of the continuous strip without interfering with the operation of the  
15 process.

A conventional hot strip mill also has a number of discrete process steps spread along a considerable length of line. Individual pieces of defective product may be removed after an intermediate step. The strip  
20 caster is a very short line with no limited possibilities to remove product after an intermediate step without severely disrupting the process.

The illustrated methods and forms of apparatus have been described by way of example only and may be  
25 modified considerably. For example, the invention is not limited in its application to processes in which the cast strip is hot rolled in line with the caster and it could be applied to strip which is simply reduced in temperature and coiled after casting. The strip may, for example,  
30 pass over a runout table after casting on which it is force cooled to a coiling temperature of the order of 660°C.

The illustrated apparatus has been advanced by way of example only and it could be modified considerably.  
35 The method of the invention enables continuous strip casting in the face of either strip quality failure or equipment failure. Equipment failure can occur anywhere

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along the line and may for example include coiler failure or deflector failure.

5 The strip defect detector can be located at other sites along the line for example, below the nip. Some defects such as meniscus marks and herringbone are most observable when the strip is red hot. The scrapping station can be located anywhere after the shear, it need not be located at the end of the line. Indeed, the strip can be diverted anywhere other than to the coilers. It is  
10 accordingly to be understood that the invention is in no way limited to the detail of the illustrated apparatus and that many variations will fall within the scope of the appended claims.

CLAIMS

1. A method of continuously casting and handling metal strip, comprising:

supporting a casting pool of molten metal on one  
5 or more chilled casting surfaces;

moving the chilled casting surface or surfaces to produce a solidified strip moving away from the casting pool;

guiding the solidified strip along a transit path  
10 which takes it away from the casting pool to a coiling station;

coiling the strip onto a coiler at the coiling station;

operating a strip shearing means so as to sever  
15 the strip in advance of the coiling station into discrete lengths;

diverting the severed lengths of strip from the coiling station to a scrap station; and

halting the operation of the strip shearing means  
20 so as to reinstate delivery of continuous strip to the coiling station and directing the reinstated continuous strip to a second coiler at the coiling station.

2. A method as claimed in claim 1, wherein a scrap bin is located at the scrap station to receive the severed  
25 lengths of strip.

3. A method as claimed in claim 1 or claim 2, wherein the operation of the strip shearing means and diversion of the severed lengths of strip to the scrap station is initiated in response to observation or  
30 detection of defects in the strip.

4. A method as claimed in claim 1 or claim 2, wherein the operation of the strip shearing means and diversion of the severed lengths of strip to the scrap station is initiated in response to malfunctioning of  
35 equipment employed in the casting or handling of the strip.

5. A method as claimed in claim 3, comprising the

steps of inspecting the strip for defects as it passes in said transit path by means of strip defect detection means located along that path and initiating operation of the strip shearing means in response to an indication from the defect detection means of defects in the strip.

6. A method as claimed in claim 5, wherein the defect detection means is operated to detect variations in thickness of the strip.

7. A method as claimed in claim 6, wherein the defect detection means comprises an X-ray gauge.

8. A method as claimed in any one of claims 5 to 7, wherein the defect detection means is operated to detect surface defects in the strip.

9. A method as claimed in any one of claims 5 to 8, wherein the strip proceeding along said transit path passes through a cooling station and the strip is examined by the defect detection means upstream and downstream of the cooling station.

10. A method as claimed in claim 9, wherein the strip is examined upstream of the cooling station for thickness defects and is examined downstream of the cooling station for surface defects.

11. A method as claimed in any one of claims 1 to 10, wherein the casting pool of molten metal is maintained by flow of molten metal from a tundish supplied alternatively by each of a plurality of ladles brought to a pouring position by a rotating turret.

12. Apparatus for continuously casting and handling metal strip comprising:

a pair of generally horizontal casting rolls forming a nip between them;

metal delivery means to deliver molten metal into the nip between the casting rolls to form a casting pool of molten metal supported on the rolls;

means to chill the casting rolls;

means to rotate the casting rolls in mutually opposite directions whereby to produce a cast strip

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delivered downwardly from the nip;

strip guide means to guide the strip delivered downwardly from the nip through a transit path which takes it away from the nip;

5 a pair of coilers at a coiling station selectively to receive the strip from said transit path;

strip shearing means operable to sever the strip in advance of the coiling station into discrete lengths; and

10 strip diverter means to divert the severed strip lengths from the coiling station to a scrap station.

13. Apparatus as claimed in claim 12, wherein a scrap bin is located at the scrap station to receive the severed lengths of strip.

15 14. Apparatus as claimed in claim 12 or claim 13, wherein there is a pair of strip deflectors at the coiling station operable alternatively to divert the strip to one or other of the coilers.

20 15. Apparatus as claimed in claim 12, wherein the strip diverter means comprises a runout table to guide the severed strip lengths to the scrap station when the deflectors or coilers are inoperative.

25 16. Apparatus as claimed in any one of claims 12 to 15, and further including strip defect detection means disposed along said transit path in advance of the coiling station and operable to detect defects in the strip.

30 17. Apparatus as claimed in claim 16, wherein there is an operative connection between the defect detection means and the shearing means such that the shearing means is operable in response to an indication from the defect detection means of defects in the strip.

18. Apparatus as claimed in claim 16 or claim 17, wherein the defect detection means is operable to detect variations in thickness of the strip.

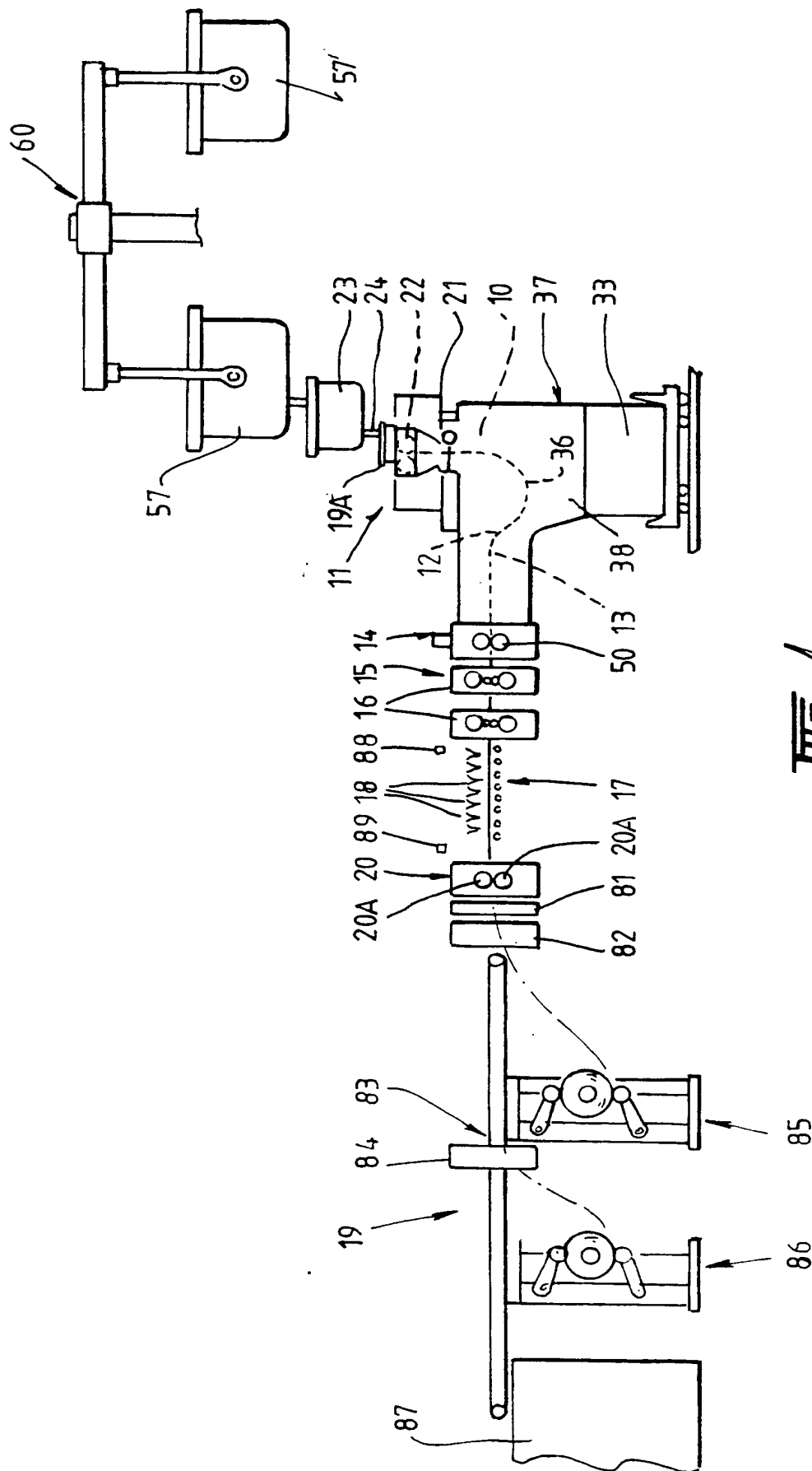
35 19. Apparatus as claimed in claim 18, wherein the defect detection means comprises an X-ray gauge.

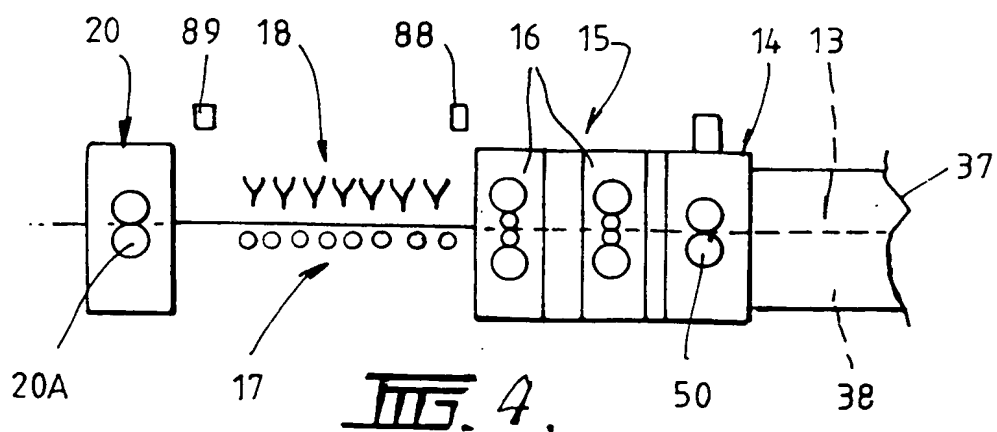
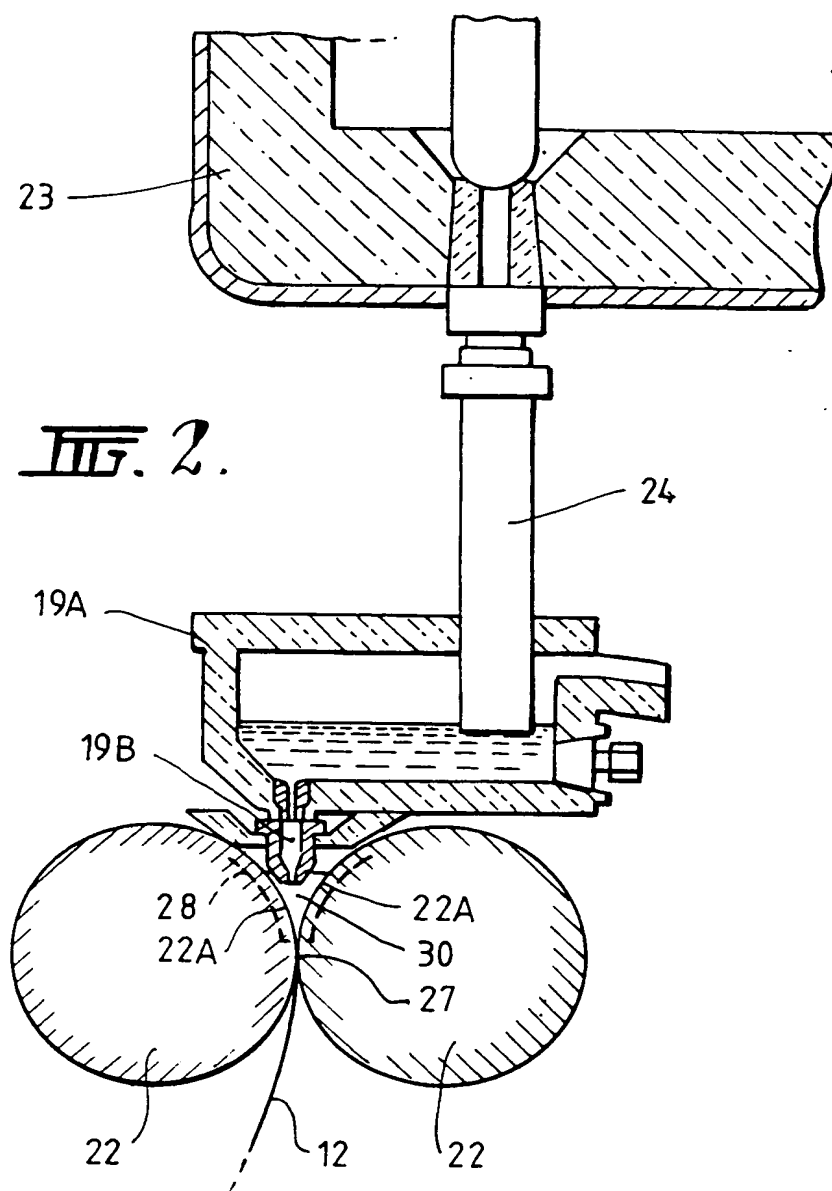
20. Apparatus as claimed in any one of claims 16 to



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19, wherein the defect detection means is operable to detect surface defects in the strip.





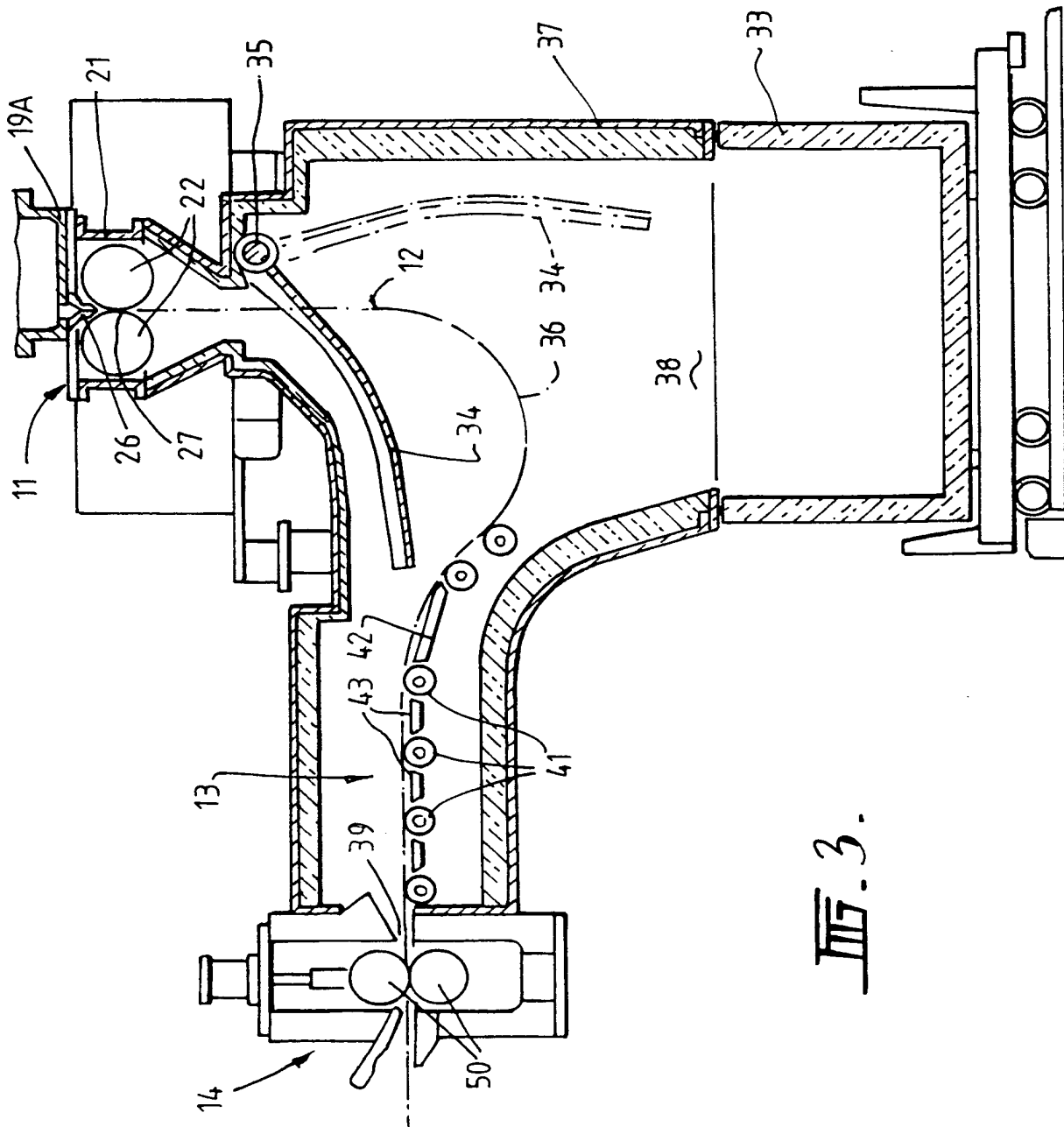


Fig. 3.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU00/00293

**A. CLASSIFICATION OF SUBJECT MATTER**Int. Cl. <sup>7</sup>: B22D 11/06, 11/126, 11/12

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC: B22D 11/06, 11/126, 11/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPAT, Key words: cut:, shear:, slic:, sever:, defect:, scrap:, inclus:, fault:, break

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|-----------|--|-----------------------|
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU00/00293

C (Continuation).

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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
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